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RESEARCH PAPER

Microbiological quality of raw milk under a scheme of good milking and storage practices in a goat production system in the Lagunera Region, Mexico

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Abstract

Dairy products provide essential nutrients when consumed and they also create rural employment. A small dairy can help a family maintain their livelihood. The objective of this study was to evaluate the microbiological quality of raw goat milk obtained during the milking-storage process using Good Hygiene Practices. The study was carried in northern Mexico, which is characterized by a desert climate. The experiment was carried in four herds, six samplings per herd with a total of 302 goats. Samples of milk extracted directly from the udder, milk extracted from the milking bucket and milk extracted from the storage bucket were analyzed. In addition, samples were taken from the milker's hands. The data were analyzed using ANOVA and the statistical difference with the Tuky test ($p < 0.05$). A significant difference ($p < 0.05$) was observed in Total Coliforms (TC) for milker's hands, milk extracted directly from the udder, milk extracted from the milking vat and milk extracted from the storage vat. However, at the time when the Good Hygiene Milking Practices GHPM treatment was stopped (June-July), higher CFU/mL of TC were observed in all stages of the milking-storage process. The pathogenic microorganisms identified were *Escherichia coli*, *Salmonella* spp. and *Shigella* spp. raw goat milk can be easily contaminated during the milking-storage process, since the common practice is to milk in the pen among other animals, manure and soil. To improve quality and sustainability parameters, it is necessary to have an exclusive space for milking as well as the implementation of GHPM. Better business alliances and better ethics between suppliers and industrial producers are also necessary.

Keywords

Commercialization, Hygiene, Milking process, Pathogenic bacteria, Total coliforms

Introduction

Goat milk and foods derived from goats are a nutritious source of fats, proteins, micronutrients, probiotics and prebiotics that can contribute to human health (Hoppe et al. 2006). The current issue in the dairy agroindustry is the demand for safe products with higher nutritional quality (WHO 2015). However, it is recognized that safety in dairy products must begin in the dairy farm where the milk is produced, so the quality and hygiene of raw goat milk is a challenge for both goat farmers and those who produce dairy products (Carloni et al. 2015; Zumbado and Romero 2015; Khaldi et al. 2021).

Food security can affect the entire agri-food chain, from food acquisition to marketing, productivity, distribution,

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access to markets and consumer health (Sani and Dahlan 2015). Food safety requires prevention to avoid foodborne diseases by evaluating foods, their components and good manufacturing practices to detect microbiological, physical and chemical contamination (Cullor 1997).

In Mexico, goat farming is one of the primary activities on which more than 1.5 million people depend and, in turn, creates rural employment (Ramírez-Rivera et al. 2017). A small dairy can help a family maintain their livelihood in the Laguna Region (Orona et al. 2013). The Lagunera Region is distinguished for producing more than 50% of the production (extensive and semi-extensive type) of goat milk in Mexico and its greatest concentration and main development takes place in marginal places. The annual production of goat milk in the Lagunera Region for the year 2023 was close to 59 million liters, generating an income of 17.5 million dollars for that year (SAGARPA-SIAP 2024).

However, during the production of goat milk, Good Hygiene Practices in milking (GHPM) are generally not applied and this allows the exponential proliferation of pathogenic microorganisms such as total and fecal coliforms, *Eschericha coli* (*E. coli*), *Salmonella* spp., *Staphylococcus aureus* and mainly *Brucella melitensis* that cause foodborne diseases such as malt fever, among other diseases (Morales-Pablo et al. 2012; Ramírez-Rivera 2017).

Some studies highlight that good hygiene practices are key during milking to obtain more hygienic and safe milk. Nevertheless, poor hygiene practices can contaminate milk with pathogenic bacteria that cause it to have a short shelf life (Lai et al. 2016; Ahmed 2022). In the Lagunera Region, hygiene during the production of goat milk is scarce or non-existent and few producers are interested in receiving training. Most goat farmers deliver or sell unfiltered or unpasteurized milk (Maldonado et al. 2011).

Kalhotka et al. (2015) and Isidro et al. (2009) mention that goat milk is an excellent culture medium for the growth of pathogenic microorganisms and other contaminants, which generally come from the environment. Producing goat milk safely is of utmost importance to be successful during production, processing, marketing and manufactured products (cheese, cottage cheese, snow, liquor and cajeta). Milk and dairy products must be free of pathogenic bacteria, antibiotics, insecticides, and herbicides and safe during consumption (Park 2016).

The above can compromise the health of consumers due to the intake of goat milk and non-safe products, which leads to a negative impact on the economy of producers (Fekadu et al. 2005; Goetsch et al. 2011; Ruiz-Romero et al. 2013). For this reason, Mexico has an Official Mexican Standard NOM-243-SSA1-2010 that specifies the mandatory use of pasteurization as a means of reducing the permissible microbial load in raw milk and dairy products.

Carrying out this type of research is necessary for producers to put GHPM into practice and thus be able to minimize contamination and the growth of pathogenic microorganisms and physicochemistry in milk, since this food is mainly used for transformation into artisanal dairy products. (Ramírez-Rivera et al. 2018).

Therefore, some studies (Ruangwittayanusorn et al. 2013; Amenu et al. 2016) indicate some key points in the milk handling process and highlight greater attention to promote hygienic practices and measure the effect of these. However, limited data on the microbiological hazards associated with goat milk are found in the literature (Asselt et al. 2017). Therefore, the objective of the study was to evaluate the effect of GHPM on the microbiological quality of raw goat milk, obtained during four critical periods of the milking and storage process.

Materials and methods

Location of experimental area, design of treatments and milk sampling

The work was carried in the southeastern Laguna Region of the state of Coahuila (25°N, 103°W) in northern Mexico, located at 1,100 masl. The climate corresponds to BWhw, which is characterized as being a desert, very dry and warm, with a cool winter and an annual average precipitation of 240 mm. The annual average temperature in the shade is 25 °C, with ranges from -1 °C in winter to 44 °C in the summer (García 1973).

A total of 26 producers with about 2,000 goats, four herds were selected using the "purposeful selection" or "convenience sampling" method proposed by Casal and Matéu (2003) and McMillan and Schumacher (2001) with some modifications with the objective of monitoring the milking and storage process of goat milk. Six samplings were taken between the months of February and July in 2019, on four caprine dairy herds, in each of the four stages of the milking process (6×4×4) with 302 goats.

The treatment was the implementation of Good Hygiene Milking Practices (GHPM) in two herds of 46 and 55 goats each, and two herds of 96 and 106 goats each, following their traditional milking scheme (Control group). The experiment was carried out for six months (February to July 2021) (Fig. 1), with the variable of the GHPM implementation that was induced by the group of researchers for 4 months (GHPM intervention). Subsequently, the other two months, the producers did it on their own (GHPM post-intervention phase). With the implementation of

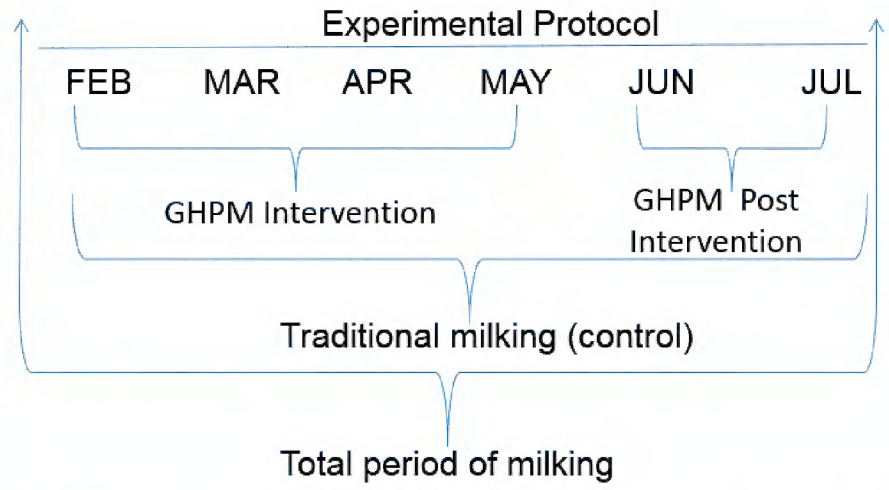

Figure 1. Experimental protocol for the treatment using good hygiene practices for milking and storage (GHPM) and the control group.

the GHPM, collaborating producers were trained in the milking place, udder management during milking, hand hygiene and the utensils to use (Maldonado et al. 2011).

The milking process and the application of the GHPM was based on the methodology described by Maldonado et al. (2011) with some modifications that were the following:

The milking process and application of the GHPM considered the following practices:

1. Washing of the utensils used in milking at the beginning and at the end (milking bucket, storage bucket, and strainer cloth).
2. Washing of hands with soap and water or the use of an antibacterial gel before and during milking.
3. Washing of teats with an iodine solution at 2% for 20 seconds and drying with a paper towel.
4. Pre-milking (to discard the plug formed on the point of the teat by disposing of the first gushes of milk).
5. Stimulation to trigger milk letdown (massage the udder and teat for about 60 seconds).
6. Sealing of the teat sphincter on the udder after milking using an iodine solution.
7. Collection of the milk in the storage bucket with straining to avoid the entrance of external pollutants (hair, insects and other impurities).
8. Covering of the storage bucket between pourings from the milking bucket.
9. Placing the storage bucket in a shaded place, keeping it as cool as possible, until it is collected or delivered.
10. Perform milking in rustic milking rooms or over cement floors, to avoid contamination from the corral floor.

The milk samples were collected in 100 mL sterile bottles; and were taken in each of the four stages of the milking and storage process, as shown in Fig. 2. The hand samples from the milked were taken with a sterile cotton swab dampened in saline solution (NaCl, 10%). The processing and microbiological analysis of the samples was performed at the Laboratory for Food Safety and Added Value of La Laguna Experimental Field of INIFAP in Matamoros, Coahuila; Mexico.

Microbiological analysis

The microbiological analyzes were carried out based on the Official Mexican Standard NOM-243-SSA1-2010, Products and services. Milk, milk formula, combined dairy product and dairy derivatives. Pertifilm™ Plates were used to count Total coliforms (TC), a method recognized by the Association of Official Analytical Chemists (AOAC) (Wallace 1995). The identification of *E. coli* and *Salmonella* spp. was based on the Official Mexican Standard NOM-113-SSA1-1994 and the Official Mexican Standard NOM-114-SSA1-1994.

Statistical analysis

The results were expressed as mean values ± SD using ANOVA, and the statistical difference was established at $p < 0.05$ using the Tukey test. The INFOSTAT Software version 2017 was used.

Results

Based on the Official Mexican Standard NOM-243-SSA1-2010, it mentions all the specifications of the microbiological quality of dairy products, they are the same for goat, cow or sheep milk and their derivatives. The results of TC (CFU/mL) count are shown in Table 1 where it is observed in the first 4 months with intervention with GHPM and Control without GHPM. Likewise, the post-intervention of the GHPM and Control without GHPM are observed during the 2 months of sampling.

Table 1. TC count (CFU/mL) in the four stages of the milking process implementing the GHPM and the Control without good practices.

Treatment	GHPM intervention			
	MH	MDU	MMB	MSB
GHPM	0 ± 0^{b}	6 ± 2^{b}	0 ± 0^{a}	58 ± 32^{b}
Control	10 ± 1^{a}	21 ± 3^{a}	0 ± 0^{a}	140 ± 24^{a}
	GHPM post-intervention			
	MH	MDU	MMB	MSB
GHPM	0 ± 0^{b}	30 ± 12^{a}	52 ± 21^{a}	305 ± 28^{a}
Control	81 ± 39^{a}	34 ± 54^{a}	68 ± 32^{a}	375 ± 60^{a}

Values are means of 3 repetitions, ± SD. Different letters indicate significant differences between columns according to the Tukey test ($p < 0.05$). MH = milker's hands, MDU = milk taken directly from the udder, MMB = milk taken from the milking bucket, MSB = milk taken from the storage bucket.

The number of TC (CFU/mL) varied significantly ($p < 0.05$) during the obtaining of goat milk in MH, MDU and MSB with GHPM intervention compared to the Control without GHPM. However, during the post-intervention there is a significant difference ($p < 0.05$) in MH with GHPM and Control without GHPM, with no significant difference ($p > 0.05$) in the other three stages of milking. In the MSB stage, the highest TC load was obtained with intervention, post-intervention and the Control without GHPM.

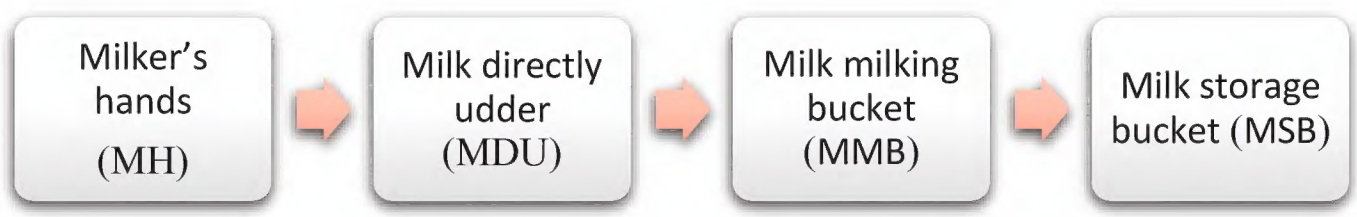

Figure 2. Critical points in the milking process for goats of the extensive system in the Laguna Region.

Fig. 3 shows the significant differences ($p < 0.05$) in the TC count (CFU/mL) in the four stages of milking, with the highest number of TCs in MSB during the six months of intervention with GHPM compared to to Control without GHPM.

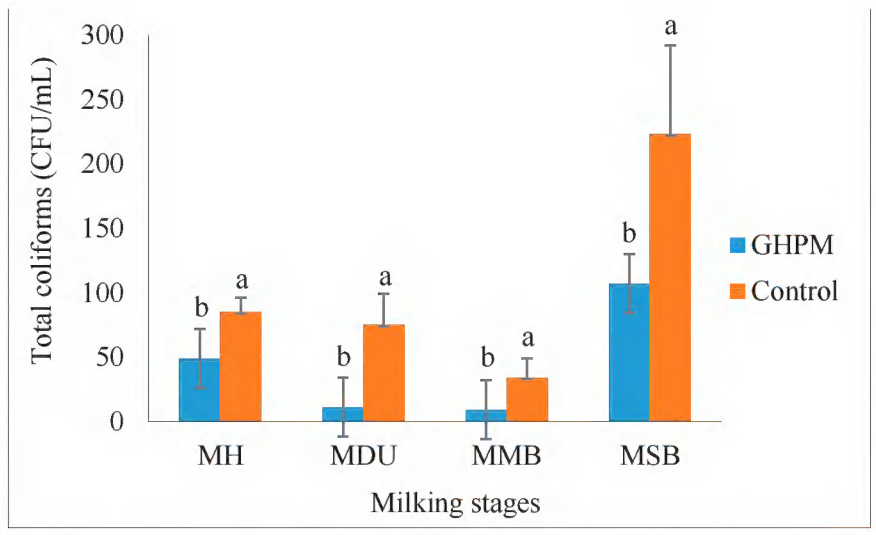

Figure 3. TC count in the 4 stages of milking with GHPM and Control without GHPM. MH = milker's hands, MDU = milk taken directly from the udder, MMB = milk taken from the milking bucket, MSB = milk taken from the storage bucket.

Fig. 4 shows the significant differences ($p < 0.05$) during the intervention and post-intervention of GHPM in the four stages of milking, with more TC in the MSB stage during the post-intervention.

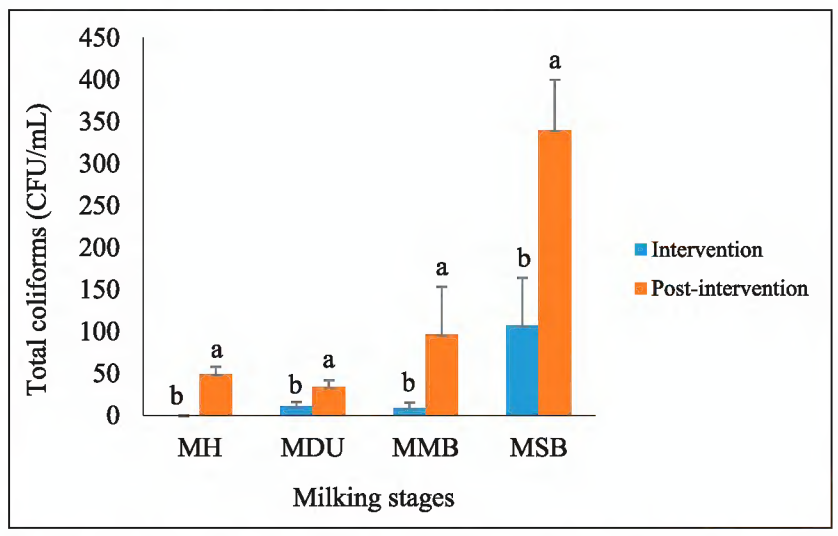

Figure 4. TC count in the 4 stages of milking during the GHPM intervention and post-intervention. MH = milker's hands, MDU = milk taken directly from the udder, MMB = milk taken from the milking bucket, MSB = milk taken from the storage bucket.

Fig. 5 shows an increase in TC in the four stages of milking during the post-intervention and Control without GHPM. However, between the MH and MDU, a significant difference ($p < 0.05$) is observed between these stages. On the other hand, there is no significant difference in MMB and MSB, with this last stage of milking having the highest TC load in post-intervention with GHPM and Control without GHPM.

Nuhriawangsa et al. (2019) describes that to obtain a high hygienic quality of raw goat milk for consumption requires GHPM implementation such as washing milking utensils (milk collection bucket and storage bucket), washing or cleaning udders, hand washing during milking with water or antibacterial gel and handling before delivering the milk to the consumer or the company to sell.

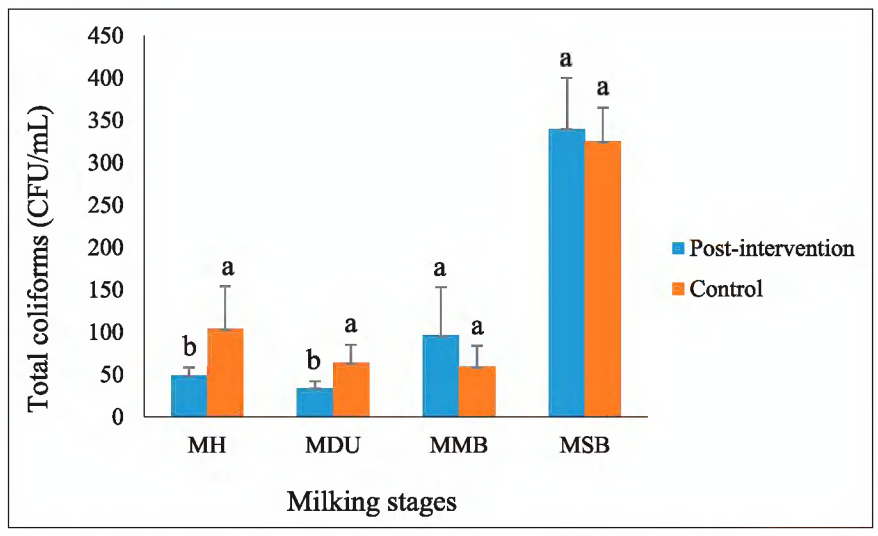

Figure 5. TC count in the 4 stages of milking during the GHPM intervention and Control without GHPM. MH = milker's hands, MDU = milk taken directly from the udder, MMB = milk taken from the milking bucket, MSB = milk taken from the storage bucket.

Identification of pathogenic bacteria

By implementing GHPM, producers reduce pathogenic bacteria during milking; therefore, Table 2 shows the pathogenic bacteria identified in the four stages of milking, comparing the herds with GHPM and Control without GHPM. The presence of pathogenic bacteria such as *E. coli* was observed in both groups. However, the highest number of total bacteria during the entire milking process was observed in the control group with 35. Regarding *Salmonella* spp. was obtained in the control group, as well as in the treatment group in the MSB stage. Furthermore, the bacteria that make up the natural microbial flora of milk were found in both groups.

Table 2. Number of pathogenic bacteria identified in the four stages of milking with GHPM and the Control without GHPM.

Bacteria	GHPM					Control				
	MH	MDU	MMB	MSB	Total	MH	MDU	MMB	MSB	Total
E. coli	2	1	1	10	**14**	8	4	6	17	**35**
Salmonella spp.	0	0	0	1	**1**	1	1	1	1	**4**
Shigella spp.	0	0	0	1	**1**	0	0	0	1	**1**
Klebsiella spp.	1	1	0	9	**11**	0	1	6	2	**9**
Providencia spp.	0	1	0	1	**2**	0	1	0	7	**8**
Aerobacter spp.	0	1	0	2	**3**	0	4	5	3	**12**

MH = milker's hands, MDU = milk taken directly from the udder, MMB = milk taken from the milking bucket, MSB = milk taken from the storage bucket.

The results of the analysis for *E. coli* show that this pathogenic bacteria was identified in the four stages of milking with the implementation of GHPM and the Control without GHPM. *Salmonella* spp. It was identified in MSB during the implementation of the GHPM and in the Control without GHPM it was identified in the four stages of milking. Having an overall count in the Control without GHPM with 69 bacteria isolated compared to 32 bacteria implementing the GHPM.

In general, the increase in TC is due to the fact that during milking the bacteria in the MSB milk bucket in-

crease and reproduce. This contamination can begin on the milker's hands or in milk taken directly from the udder, followed by milk taken from the milking bucket, and ending in milk from the storage bucket. Likewise, the identified pathogenic bacteria are considered an indicator of the hygienic conditions of raw goat milk production that these bacteria belong to the Enterobacteriaceae family. Our results agree with Kovácová et al. (2021) finding bacteria between 3.49 ± 0.13 log CFU/mL to 7.32 ± 0.19 CFU/mL in raw goat milk.

Discussion

Mexico has an Official Mexican Standard NOM-243-SSA1-2010, products and services for fluid milk, milk formula, combined dairy product and dairy derivatives, establishing the maximum permissible limits for Total coliforms is ≤ 20 CFU/mL., in *Salmonella* spp. absent and *E. coli* ≤ 3 CFU/mL in fluid milk. However, it does not specify the origin of the milk (goat, cow or sheep). Likewise, Mexico has a specific standard for raw goat milk, which is NMX-F-728-COFOCALEC-2007. However, nothing else specifies the mesophilic aerobic total bacteria count and somatic cell count in raw goat milk. For this reason, Mexico does not have an official standard for raw goat milk for sale at the farm level from storage vats that specifies the permissible limits of total coliforms and identification of pathogenic bacteria such as *Salmonella* spp. and *E. coli*, especially *Brucella melitensis* that causes malt fever, as they are microorganisms of utmost importance in public health (Palomares et al. 2021).

The results of the study at the farm level show that the implementation of GHPM causes bacteria belonging to the Enterobacteriaceae family to considerably decrease in raw goat milk during milking and storage. However, bacteria increase when they stop implementing GHPM, giving similar results to Control herds without GHPM. The producer's continuity in the use of good hygiene practices in milking, production and conservation is essential to obtain quality milk (Isidro et al. 2009; Nuhriawangsa et al. 2019).

It is essential to work with local communities to improve their understanding of milk safety risks to facilitate a change in practices (Amenu et al. 2016). On the other hand, as long as the producer does not receive a tangible monetary reward from the dairy industry for producing milk of better physical-chemical quality, he will not be motivated to incorporate GHPM permanently (Salinas-González et al. 2015; Lencho et al. 2018).

Park, (2016) mentions that the production of raw goat milk must be started by milkers during milking to obtain high quality milk because the flavor cannot improve later during the different stages of dairy product production. The general principle of quality dairy foods is the better the raw milk, the better the processed products. Even though there is technology in the management of goat milking to obtain safer and good quality milk, the reality is that there is an absence of adoption of these GHPM by small producers of raw goat milk (Isidro et al. 2009; Morales-Pablo et al. 2012; Suranindyah et al. 2015).

The main pathogenic bacteria found naturally in goat milk, as well as cow and sheep milk, are *Salmonella* spp., *E. coli*, *Staphylococcus aureus* and *Brucella melitensis*, it is practically impossible to eliminate these pathogenic bacteria during milking. Contamination in raw goat milk can originate from the animal itself (udder), milker's hands, vats for milk collection, storage vats, environment and the water supply for washing utensils among others. There have been outbreaks of food-borne diseases due to the consumption of goat milk because it has these pathogenic bacteria (IMSS 2024; Secretary of Health 2024).

Conclusion

The results of this study confirmed that implementing GHPM reduces contamination by pathogenic bacteria during milking, since raw goat milk may be contaminated along the completely milking process, or during the collection and storage of the milk, due to insufficient cleanness of the udder, lack of sanitation on the milker's hands, or incorrectly disinfected utensils. Milking the goats in the corral contributes to milk contamination by pathogenic microorganisms. Therefore, the producer himself needs to be convinced of the need for producing milk in a clean, green and ethical environment; and on the industry's side, there needs to be a parallel commitment to pay a fair price for milk which is of better quality, both quantitatively and qualitatively, and in this way contribute to the sustainable development of the region. There are several studies on the composition, quality and safety, most of which are in cow's milk, there is still not enough information from local studies on the contamination of goat's milk. These results can provide compelling data to help understand the quality and safety of milk during manual milking.

Authors' contribution

L.M. Isidro-Requejo, F. Pastor L. and J.A. Maldonado collected and described the information on microbiological and physical hazards; L.M. Isidro-Requejo and H. Salinas-González wrote and the last one was responsible for drafting and submitting the manuscript. U. Figueroa-Viramontes was involved in defining the study setup, statistical analysis, reading and commenting on the paper.

Conflict of interest

There are no conflicts of interest.

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Supplementary material

Supplementary material 1
GHPM technology and sample photos (pdf)
Link: https://doi.org/10.3897/ejfa.2024.121230.suppl1